Internal Waves in Straits (IWISE): Observations of Wave Generation

David M. Farmer
Graduate School of Oceanography (educational)
University of Rhode Island
Narragansett, RI 02882
Phone: (401) 874-6222 fax (401) 874-6889 email: dfarmer@gso.uri.edu

Jae-Hun Park
Graduate School of Oceanography (educational)
University of Rhode Island
Narragansett, RI 02882
Phone: (401) 874-6514 fax (401 874-6728 email: jpark@gso.uri.edu

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LONG-TERM GOALS

The long term goals are to use observations and analysis of stratified flow past complex topography to understand how internal tidal interaction in straits is responsible for the generation of large amplitude high frequency internal waves.

OBJECTIVES

Our objectives are to build and deploy a 2-D array of pressure equipped inverted echo sounders so as to observe the generation of internal waves generated by tidal interaction with topography in Luzon Strait, and to interpret the results using appropriate models of internal wave formation and evolution.

APPROACH

Our approach requires construction of an array of pressure equipped inverted echo sounders (see Li et al. 2009). Our plan called for eight instruments, but the size of the planned array has now been increased as a result of a separate ONR-DURIP, motivating redesign of the array based on model calculations at different sections across the ridges.

WORK COMPLETED

At this time model analyses of the generation region using the MITgcm have been carried out. Together with modeling and data analysis activities completed under the NLIWI project (see Farmer et al., 2009), these results are providing guidance for the array deployment. Instrumentation construction is underway, with acquisition of components and building of electronic boards. Model calculations have been carried out by Li Qiang; instrument development is being carried out by Randy Watts and the Equipment Development Lab. A smaller array has now been deployed in Luzon Strait as part of a

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Pilot Study (see Fig. 1) with the assistance of Matthew Alford. These instruments will be left in place until the spring of 2011.

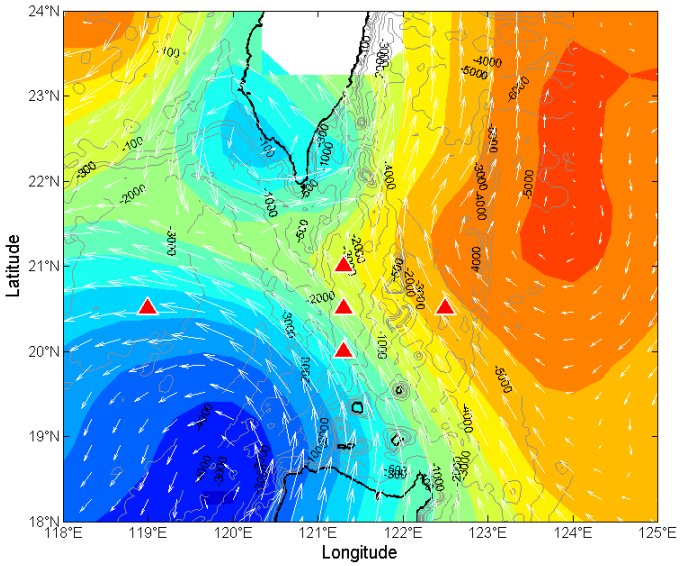

Fig 1: Pilot study deployment of pressure equipped inverted echo-sounders.

RESULTS

As yet, we have no data from our Pilot Study deployments. Detailed analysis of nonlinear internal waves carried out under the NLIWI program and continued in to IWISE have provided results that are critical in designing the Luzon Strait deployments and interpreting results as they become available. Li & Farmer (2010) carried out a series of model calculations to explore potential mechanisms responsible for the nonlinear waves observed in the deep basin of the South China Sea. Despite the obvious nonlinearity of these waves, it appears that a reasonable first order description of their generation can be explained by a 2-layer linear model. Inverted echo sounder data from PIES can only provide information on the first internal mode, but even such a simplified representation appears to be useful in analysing the generation process. Doppler effects associated with a steady flow, such as might be imposed by the Kuroshio intrusion, help explain an apparent dearth of nonlinear internal waves in the winter months, when the intrusion generally occurs. Alternative explanations for lack of remotely sensed signals of nonlinear internal waves in winter include the effects of higher winds, which make surface effects due to waves less apparent. There have, to our knowledge, been no direct measurements to test either hypothesis. The instruments deployed for our pilot study should provide helpful information on this aspect.

Calculations carried with a 2-D implementation of the MITgcm, have been used in preliminary interpretations with both remotely sensed characteristics of the Kuroshio and our simultaneously acquired inverted echo-sounder measurements.

Altimetry measurements of the Kurioshio are shown in Fig. 1 in August 2005 (*left*) and August 2007 (*right*). In 2005 the Kuroshio followed a slightly curved path over the eastern ridge,

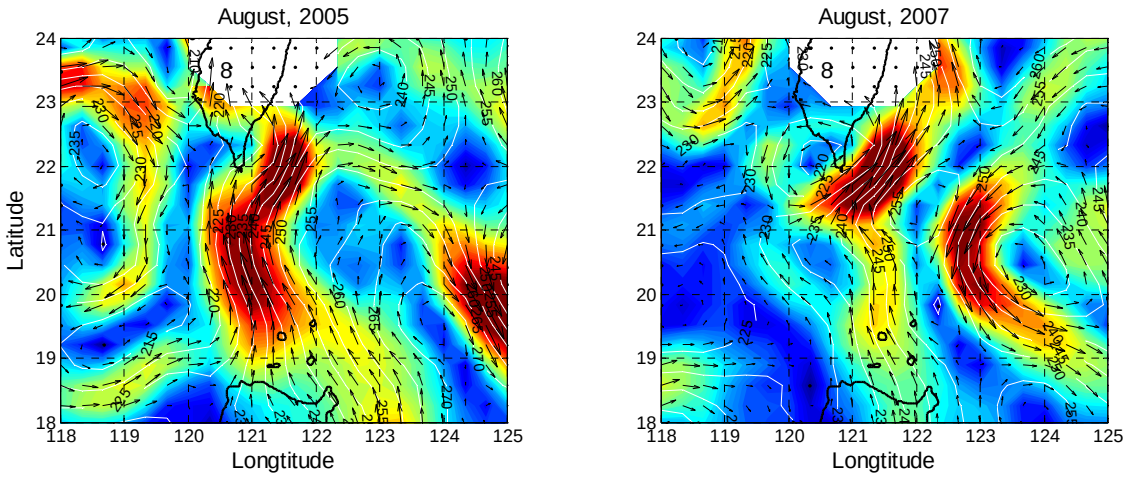

Figure 2: Sea surface height based on radar altimetry (white contour) for August 2005 and August, 2007. Black arrows correspond to surface geostrophic velocity (u,v) derived from SSH and the color represents the corresponding speed.

imposing a quite modest adjustment to the zonal barotropic component, whereas in 2007 there was a significantly stronger easterly component, especially north of 21N. However, it can be demonstrated with internal tide generation models (Li & Farmer, 2010) that an easterly flow over the eastern ridge leads to a larger and steeper internal tide radiating to the west. Figure 2 shows the corresponding measured internal tide for each case (predicted tidal forcing over the ridge is almost identical in each year (*red and blue time series in upper panel*).

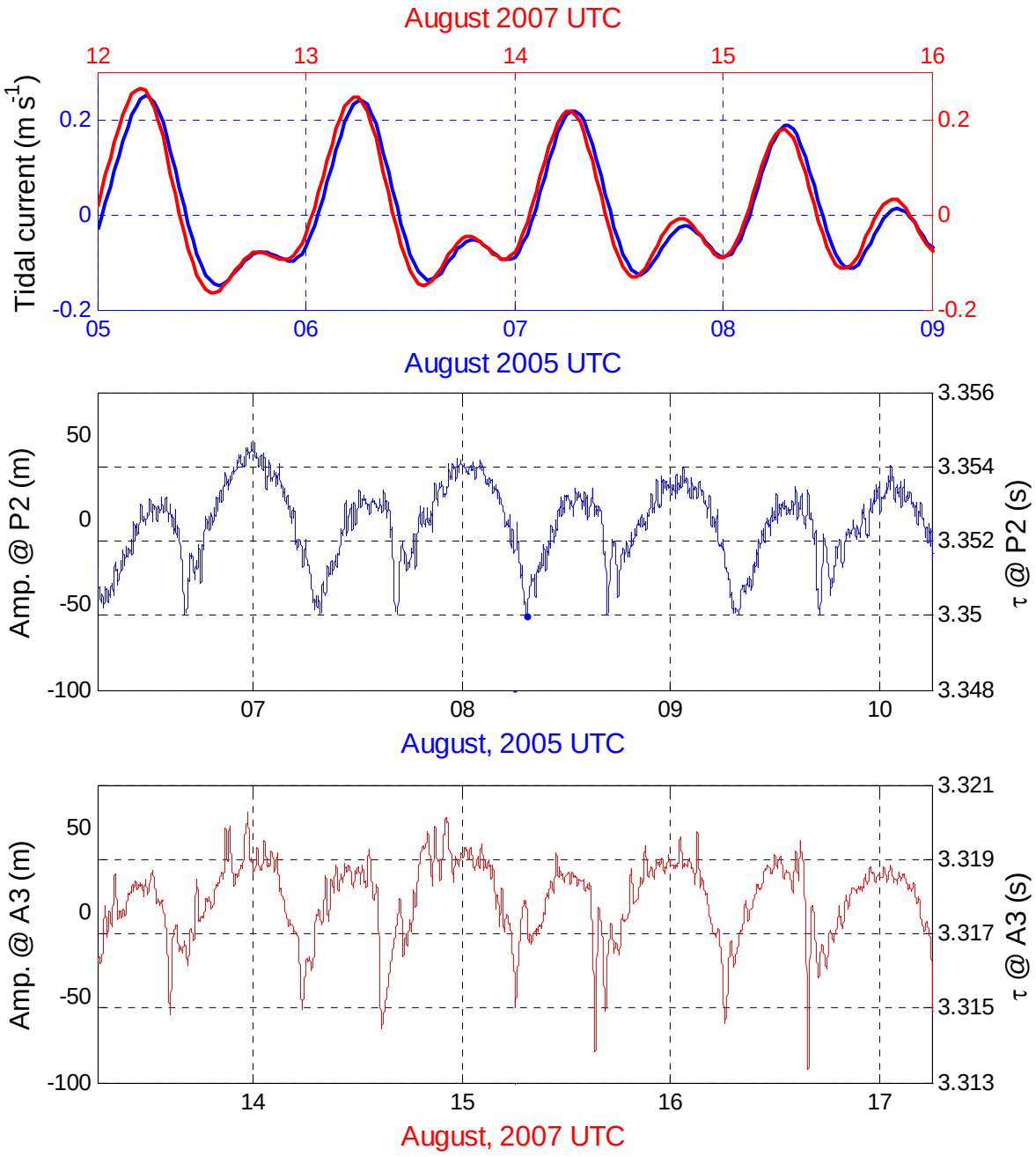

Fig. 3: Top panel shows TPXO tidal current predictions over the east ridge of Luzon Strait. Middle panel shows corresponding inverted echo sounder time series at station P2 in 2005. Lower panel shows inverted echo sounder time series at the nearly identical location of station A3 in 2007. Note that the internal tide and nonlinear internal waves are larger in 2007 than 2005, an effect attributed to the easterly component of the Kuroshio in 2007.

Note the significantly larger amplitude internal tides and high frequency nonlinear internal waves in the 2007 time series, coincident with the stronger eastward component of the Kuroshio. These results are consistent with the MITgcm calculations. The Pilot Study observations should provide us with an opportunity to explore these effects in detail.

IMPACT/APPLICATIONS

The impact of our work to date is two-fold: instrumentation currently being constructed is now deployed in a pilot study in 2010 and an extended array will be deployed in a comprehensive field program in 2011. Our initial modeling and analysis suggests that if there is a Kuroshio intrusion in the winter of 10/11, we should acquire excellent measurements of its presence and its effects on nonlinear internal wave generation.

RELATED PROJECTS

ONR project – Nonlinear Internal Wave Initiative

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